Fertilizer Placement Study

OMAFRA funded project: Optimizing Best Management Practices for Container Nursery Fertilizer Application in Ontario

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Prepared for:
Landscape Ontario Horticultural Trades Association
Milton, Ontario

Project Lead:
Dr. Jeanine West, PhytoServ

phytoSERV
SERVING GROWERS

Key Contributors:
Dr. Ann Huber, Soil Resource Group
Jen Llewellyn, OMAFRA
John Mantel, Connon AVK Holdings
Dr. Darby McGrath, Vineland Innovation & Research Centre

HORTICULTURAL TRADES ASSOCIATION
landscape ontario.com
Green for Life!

7856 Fifth Line South, RR 4, Milton, ON L9T 2X8
Phone: 905-875-1805 • Fax: 905-875-3942
www.landscapeontario.com

Executive Summary

The key findings of this study are:

1. Fertilizer placement method does significantly impact the level of fertilizer nutrients in overhead irrigated container leachate and can be used as a tool to reduce nutrient levels in container production runoff, where appropriate.
2. Topdressing and dibbling of controlled release fertilizer generated the lowest level of nutrients in container leachate samples from overhead-irrigated container nursery crops compared to all other treatments. This was especially true for the levels of phosphorus in the leachate in the first month after potting, when nutrient losses can be highest. Subsurface dibbled fertilizer placement (e.g. Dibble 2 or Dibble Layer) resulted in approximately 20% savings in fertilizer costs over Incorporated placement, and decreased phosphorus levels in the leachate by at least 50%. Further, these treatments resulted in similar tissue analysis, plant quality and marketability by the end of the project compared to Incorporated placement.
3. Subsurface dibbling in two discrete clumps (Dibble 2), in layer (Dibble L), and topdressing with the Polyon Cohesion (TD Cohesion) product also significantly decreased nitrate-nitrogen levels in the leachate compared to the Incorporated benchmark. Note that while Dibble Layer and TD Cohesion treatments had only one replicate, there is evidence that these treatments have great potential for minimizing nutrient levels in container leachate.
4. Container media additives, such as Alum (potassium aluminum sulphate), can help reduce the amount of dissolved and total phosphorus leaching from the bottom of the container. The Zeolite additive gave the greatest reduction in nitrate-N while Wollastonite (both incorporated and in a layer) gave some reduction in nitrate-N levels of the leachate. On the negative side, the Alum 65 treatment allowed excessively higher levels of nitrate-N in the leachate throughout the sampling season, compared to all other treatments.
5. The use of additives may not be financially feasible because the benefits may not be worth by their extra cost and also the extra labour required to incorporate them into the media. These additives may also increase the leachate losses of other nutrients such as nitrate-nitrogen, potassium, aluminum and sulphates. High rates of Alum and Zeolite should be monitored since they were found to increase salt levels in leachate (sulphate, sodium) and could impact overall crop health.
6. Fertilizer placement method is not a simple management tool to reduce nutrient content in container production runoff. Several factors must be considered when choosing fertilizer method. The most conservative fertilizer placement method for nutrient conservation may not be appropriate for all nursery crops because of differences in crop needs, production cycle or irrigation method.
7. Fertilizer placement method can significantly impact root structure (e.g. subsurface dibbling). This may impact root growth when the nursery crop is planted out into the landscape or forest, especially for shade trees. Further research is required to evaluate this treatment effect.

Introduction

Because most outdoor container production systems are open systems, it is difficult to ensure that all of the container runoff is captured for recycling. Decreasing nutrient impacts at container nurseries is primarily limited to irrigation and runoff management strategies. This study was undertaken to evaluate the effect of fertilizer placement methods on the nutrient content of container leachate at several commercial farms in Ontario.

It should be noted that the results of this study are presented as levels of fertilizer nutrients from undiluted, individual container leachate samples that would contribute only a small volume to the total container bed runoff. In an overhead irrigated, commercial production system, the leachate exiting the bottom of the container is diluted heavily by overhead irrigation runoff and precipitation (as much as 20 times). Therefore, the results from the container leachate analyses in this study are not indicative of container runoff nutrient levels and should not be used to quantify environmental impact in a direct manner.

Best Management Practices (BMPs) have been implemented throughout the nursery sector to minimize environmental impact. These practices are often site-specific and can include activities or scheduling adjustments, installation of technologies, or changes in growing parameters to minimize water and nutrient losses. The implementation of BMPs is designed to improve environmental stewardship without compromising crop quality. Container grown crops produced in open, overhead-irrigated beds have the potential to move nutrients off-farm via irrigation runoff. Runoff management is one of the main focus areas for reducing off-farm nutrients, and can include considerations of fertilizer placement, rate and product choice.

The four R's of nutrient management are: the right rate, the right time, the right place, and the right product. This study represents an excellent example of how placement can significantly improve nutrient management and prevent unintentional loss of fertilizer through the production process. Controlled-release fertilizers (CRFs, with 6% P or lower) are strongly recommended for nursery growers, and in fact, are the standard for outdoor nursery container production. However, fertilizer placement is important, and can impact the amount of nutrients that can leach from the pot along with other critical factors such as irrigation practices, media and plant growth needs. The fertilizer product type is also a factor in plant growth and leaching potential, since many CRF products are available on the market and they have a wide range of release patterns and longevity.

The results of this study will be used to help nursery growers make more informed decisions about fertilizer use to help reduce their impact on the environment. The results of this study will also support the *Best Management Practices for Container Nursery Production* manual, a voluntary self-assessment guide that helps growers to evaluate and reduce nutrient levels in their runoff and recapture ponds.

Methods

In cooperation with container nursery growers, this project consisted of a series of on-farm fertilizer management studies (delivery, formulation, rate) to evaluate potential for reducing environmental impact on surface water quality in the Lake Erie drainage basin. The study compared the impacts of controlled release fertilizer placement methods (i.e. incorporating into the media, top-dressing, or subsurface dibbling) on container grown *Weigela florida* 'Bristol Ruby'. In addition, comparisons included fertilizer type, rate, and the addition of agents to help reduce nutrient leaching or minimize spillage from wind throw.

Fertilizer application methods were compared through the following experiments:

a) three application methods (Incorporated, Topdress, Subsurface Dibble 2) were compared at farms using the same fertilizer type and rate, similar smooth-walled plastic containers with drainage holes at the bottom and similar media consisting mainly of aged bark and peat-moss,
b) at sites using the Incorporated method, a nutrient sequestering compound was added to the media (e.g. zeolite) to evaluate its efficacy at minimizing nutrient loss during leaching,
c) at sites using the topdressing method, a cohesion agent or specialized 'sticky' fertilizer formulation (e.g. Polyon Cohesion) was used to evaluate its efficacy at minimizing topdress spillage, and
d) at sites using subsurface dibbling method: a layer versus two distinct dibble subsurface placements was used to evaluate its efficacy at minimizing nutrient loss in container leachate.

In addition, two farms had performed in-house trials in previous years and were consulted to share the knowledge that they had gained.

Treatment/Trial Setup

Weigela florida 'Bristol Ruby' were potted in #3 container pots on July 9 and July 10, 2015 at all four sites. Details for treatments at each site, including the number pots prepared, the number of replicates, the amount of fertilizer added (CRF) and the amount and type of any additives are in Table 1. Samples were taken of unfertilized media at each site prior to media preparation for the trial and submitted for media analysis in addition to organic and dry matter content, SGS Agri-Food Laboratories, Guelph, ON.

Sampling and Data Collection

Pour-through tests were performed 1, 2, 3, 4, 6, 8, and 12 weeks after potting. The leachate from each of the replicate pots was pooled, and stored in a cooler for a maximum of 12 hours until submitting for complete analysis (SGS Agri-Food Laboratories, Guelph, ON), as well as for total and dissolved (soluble fraction) phosphorus at SGS Canada (Lakefield, ON). An irrigation/source water sample was taken at each site on every sampling date and submitted for the same analyses. To compare all treatments, the average sums for each treatment at each site were converted to percentage difference from the benchmark treatment (Incorporated), and then averaged across all sites for each treatment. The data was plotted such that the difference from the benchmark treatment (set at 0%) could be visualized.

Water applied to the crop by both irrigation and precipitation was tracked, as were volumes (total water from precipitation and irrigation) across the growing area where the trial plants were located. Temperature data was also collected at all sites, and compared to Weather Underground data from local stations.

At the end of the trial, observations were made of overall appearance, leaf colour, and root structure. Media and tissue samples were also collected on the last day of the trial. Standard greenhouse media analysis was performed by SGS Agri-Food Laboratories (Guelph, ON). Mature vegetative leaves were collected from all plants within a replicate group and pooled before submitting for standard tissue analysis by SGS Agri-Food Laboratories (Guelph, ON).

Table 1. Treatments for the Lake Erie Fertilizer Placement Study 2015

Treatments at Each Farm Site	# Pots	# Reps	#g CRF*	#g Additive	Additive
Trial Farm 1 (Topdress Farm)					
Topdress	10	2	55		
Dibble 2	10	2	40		
Incorporated	10	2	50		
Topdress (TD) with Cohesion	10	2		55	Polyon Cohesion 19-5-12 (5-6mo)
Trial Farm 2 (Incorporate Farm)					
Topdress	10	2	55		
Dibble 2	10	2	40		
Incorporated	10	2	50		
Incorporated with Wollastonite	5	1	50	40	Wollastonite (mesh 200)
Incorporated with Wollastonite Layer	5	1	50	40	Wollastonite (mesh 200)
Incorporated with low Alum	5	1	50	6.5	Alum (potassium aluminum sulphate)
Incorporated with low Alum Layer	5	1	50	6.5	Alum (potassium aluminum sulphate)
Incorporated with Zeolite	10	2	50	750	Fine Zeolite
Trial Farm 3 (Dibble Farm)					
Topdress	10	2	55		
Dibble 2	10	2	40		
Incorporated	10	2	50		
Dibble as Subsurface Layer	10	2	40		
Trial Farm 4 (Incorporate Farm)					
Topdress	10	2	55		
Dibble 2	10	2	40		
Incorporated	10	2	50		
Incorporated with Wollastonite	5	1	50	40	Wollastonite (mesh 200)
Incorporated with Wollastonite Layer	5	1	50	40	Wollastonite (mesh 200)
Incorporated with low Alum	5	1	50	6.5	Alum (potassium aluminum sulphate)
Incorporated with low Alum Layer	5	1	50	6.5	Alum (potassium aluminum sulphate)
Incorporated with high Alum	10	2	50	65	Alum (potassium aluminum sulphate)

* Polyon 16-6-12 (5-6mo)

Results/Discussion

Container Leachate

Outstanding differences were noted in the pour-through leachate concentrations between the three main treatments (Topdress, Dibble 2 and Incorporated). Some treatments (e.g. Dibble 2 and Topdress) had much lower phosphorus levels (Figure 1) compared to the Incorporated method, nitrate-nitrogen levels in the leachate actually increased in the Topdress treatment compared to the Incorporated benchmark and the Dibble 2 placement (which actually had even less nitrate-N in the leachate). Differences between the sites were evident when the replicates at the four different farms were compared (Figure 2). Therefore, the impact of all nutrients in the leachate, the media type, and the irrigation practices must be evaluated before determining the 'best' fertilizer application method for nutrient management.

The percent difference of the treatments compared to the Incorporated benchmark treatment (set at 0%) is illustrated in (Figure 3). Standard error of the means are shown as error bars. This figure clearly illustrates the advantages of the Dibble (Dibble 2 and Dibble Layer) and TD Cohesion treatments in decreasing phosphorus, nitrate-N and potassium. Note that TD Cohesion and Dibble Layer treatments had only 1 replication, so the potential variability of the result is unknown. It is important to consider the additional variation that may be present with topdressing treatments, as variable surface wetting from irrigation events and precipitation can influence the resulting leaching concentrations. There were substantial differences between the four sites (data not shown), indicating that irrigation and media type can influence the results.

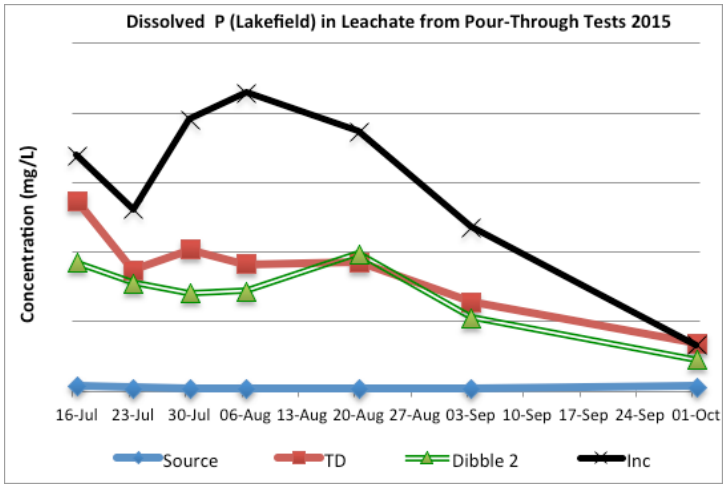

Figure 1. Trend of leachate dissolved phosphorus concentrations in the 12 weeks after potting.

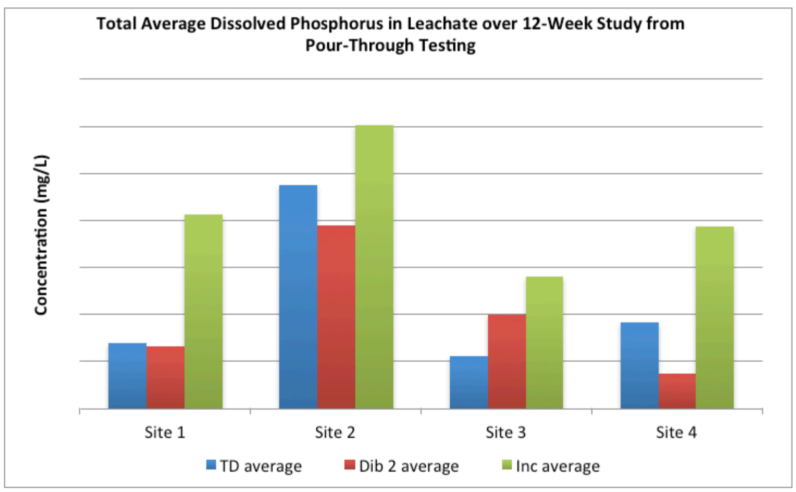

Figure 2. The seven pour-through concentrations were summed to visualize across-site differences for the three main fertilizer placements. Each bar represents 2 replicate leachate sample groups at each site.

ADDITIVES

The Wollastonite additive (incorporated and layered) did slightly improve the phosphorus and nitrate-N compared to the Incorporated benchmark, but not to the same degree. The impact on leachate from the Alum additive (all three treatments) is clearly illustrated in Figure 3, where the potassium, aluminum and sulphate-S levels are all much higher than the Incorporated control (Polyon only). The same amount of Polyon fertilizer was present in the Incorporated treatment as all the Alum treatments, the only difference was the Alum additive (rate and application method varied). The effectiveness of the aluminum additions may be improved in future experiments by slightly increasing the incorporated amounts. Zeolite addition resulted in increased sodium levels, although was effective for potassium and chloride removal While effective at retaining some elements in the pots, the potential impacts on crop health and presence of these additives in the leachate must be considered, in addition to the cost of the product.

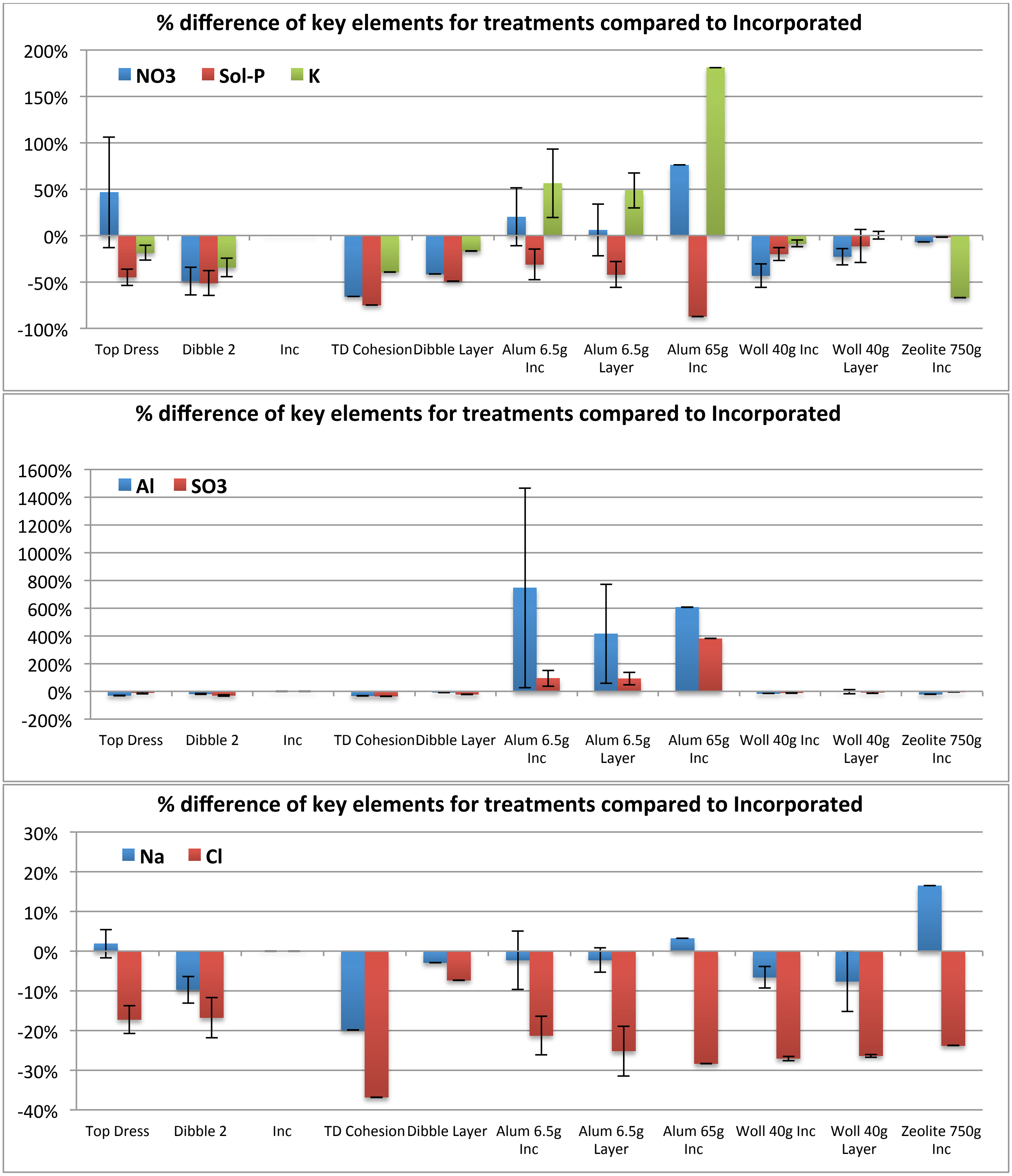

Figure 3. The percent difference for each treatment from the Incorporated benchmark for the sums of the seven pour-through sample dates (corrected for between-site differences, standard error bars shown).

Results from Other Nurseries

Farm Site 5 performed a series of trials in 2014 related to fertilizer placement in an effort to improve root growth. They compared a treatment with one discreet pile of fertilizer prills on the top of the media surface (but under the weed management covering of sawdust) with the standard incorporated method for fertilizer application on a variety of young plants (cuttings, seeds, and rooted cuttings/plugs). Root growth was particularly intense under the dibbled treatment, but only if irrigation emitter was adjacent to the pocket of fertilizer prills. When the drippers were placed away from the fertilizer, the root growth was minimal. Shoot and root growth varied between genera tested. Measurements of electrical conductivity (EC) had no consistent trend between the two treatments. Overall, the nursery concluded that they could decrease the amount of fertilizer applied and maintain acceptable root and shoot growth by providing fertilizer in a small pocket under the weed barrier (similar to a dibble point) as long as there was adequate moisture available.

Observations over years of small trials with topdressing, dibbling and incorporating fertilizers on a wide range of plant material have led Farm Site 6 to some key conclusions:

- Topdressing is their preferred method of fertilizer application
- Topdressing allows the farm to 'control' the degree of early release of nutrients
- Crops that require a lot of fertilizer early in the growth season perform well with dibbled fertilizer placement as long as irrigation (i.e. a drip stake) provides sufficient moisture
- Crops that require very little fertilizer early in the growing season perform better with topdress placement. Their goal is to only provide nutrition to the plant when it needs it, and not before.
- Media for potting is often warm (or even 'hot') and moisture can initiate release of nutrients from CRF's even before potting.
- The very stringent use of water at Site 6 affects their approach to fertilization. This farm is considered extremely conservative in their water use, and fertilizer release is highly dependent on moisture as well as temperature.

Media and Plant Analyses

MEDIA

Container media at each of the four sites studied during 2015 were quite different from each other, although all were unfertilized flowering shrub media (approximately 70% bark, 20% peat, 15% compost). During potting, the media at Site 2 was found to be quite fine. In contrast, Sites 3 and 4 had very coarse media, with large bark chunks present. In fact, some bark pieces were removed from the base mix during potting at these two sites, as they didn't fit well in the pots. However, total porosity measurements made on this media and were determined to be 70, 73, 70 and 84% for Sites 1-4 respectively. Differences in watering/irrigation practices at the farms could be an additional factor in the nutrient leachate composition from the four media types. Laboratory testing of the media prior to fertilizer or additive agent addition demonstrated that there were not large differences between the four media types for all key elements except for sulphate-S (Figure 4). The media at Site 1 appeared to have the highest sulphate-S levels, with Sites 2, 3, and 4 containing lower levels. Testing of the media at the end of the trial period demonstrated no significant differences between any of the treatments or the sites, with very little fertilizer remaining in the saturated paste (data not shown).

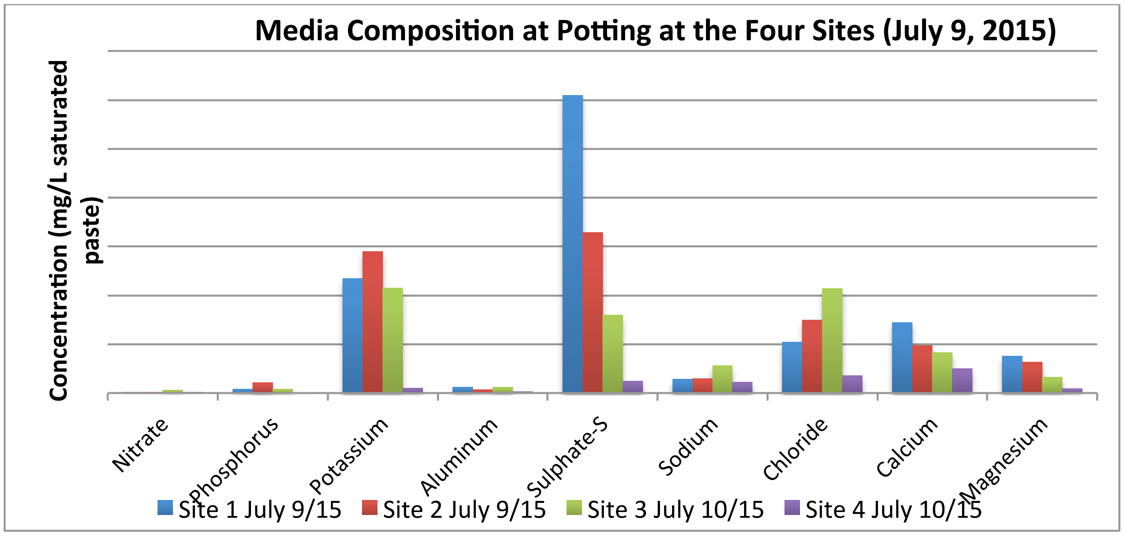

Figure 4. Media composition at the four trial sites at the beginning of the trial (before adding any fertilizer, and before potting). Each participating farm used a slightly different media.

TISSUE & ROOTS

Tissue analysis of the youngest, fully matured vegetative leaves was performed at 12 weeks after potting, at the end of the trial. Only the results of the three main treatments (Topdress, Dibble 2 and Incorporated) are shown, with standard deviation bars (Figure 5). No significant differences were observed between these three main placement treatments, and this result is particularly important when related to the original amount of fertilizer added to each pot (Table 1). The Dibble 2 fertilizer amount added was 20% less than the Incorporated benchmark method, and 27% lower than the Topdress method. Visual observations of the plants at the end of the trial further corroborate that the tissue and overall plant health was not compromised with the Dibble 2 fertilizer rate. Leaves appear equal in colour to the Topdress and Incorporated placement methods. However, the Wollastonite and Alum additives resulted in yellow leaves.

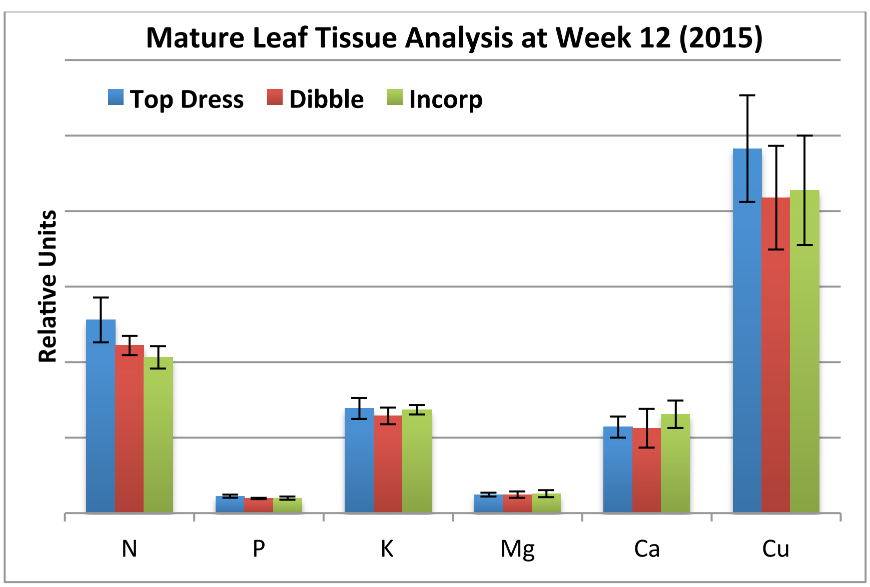

Figure 5. Tissue analysis from mature vegetative leaves at the end of the trial. Only results from the three main treatments are presented here (Topdress, Dibble 2, Incorporated). Bars are standard deviation.

Root structure differences were striking between the three main treatments (Topdress, Dibble 2 and Incorporated), and reflected the location of the fertilizer (Figure 6). The Topdress plants (Topdress and TD Cohesion) had fibrous roots mainly located near the top of the pot, as did the Dibble Layer treatment. The Dibble 2 plants had a high concentration of roots located in pockets around where the fertilizer prills were placed. All the treatments using incorporated placement had a high concentration of roots at the bottom of the pot. The distinct differences in root structure clearly suggest that placement of fertilizer is very important for nutrient uptake, and the roots will grow where fertilizer is available in the pots. When coupled with the reduced potential for leachate of nutrients, this research supports placing fertilizers near the top of the pot for improved nutrient management. Considering the reduced amount of fertilizer, it is very encouraging to observe excellent roots and canopy growth for the plants grown with the dibbled fertilizer. The variation of root structures between the main treatments warrants further examination of plant development following transplantation.

Figure 6. Pressure washed roots from the three main fertilizer placement treatments (Topdress, Dibble 2 and Incorporated).

Precipitation, Irrigation, and Temperature

Historical weather from each farm site (Figure 7) was collected and plotted, including minimum and maximum daily temperatures, and total precipitation, and compared with local weather station data. In addition, total water applied (combination of both irrigation and precipitation events) was recorded throughout the trial. Irrigation records were also provided by all farms (Figure 8). Total rainfall amounts at each site for the three-month study period are detailed in Table 2. In addition, the water applied to the crop at Site 4 was recorded across the growing area, and the minimum and maximum levels are reported in Table 3. Total water applied, through irrigation and precipitation, can impact when fertilizer is lost through leaching. If the nutrients are released too soon then late/slow-feeding plants may not get nutrients when they need it. Without sufficient water (and heat) then early-heavy feeders may not get adequate nutrients, as the prills will not release in time. If there is sufficient water to move nutrients towards the bottom of the pot then root development may intensify in that area. There are many possibilities based on the crop's needs, water availability, and release curves of the fertilizer used.

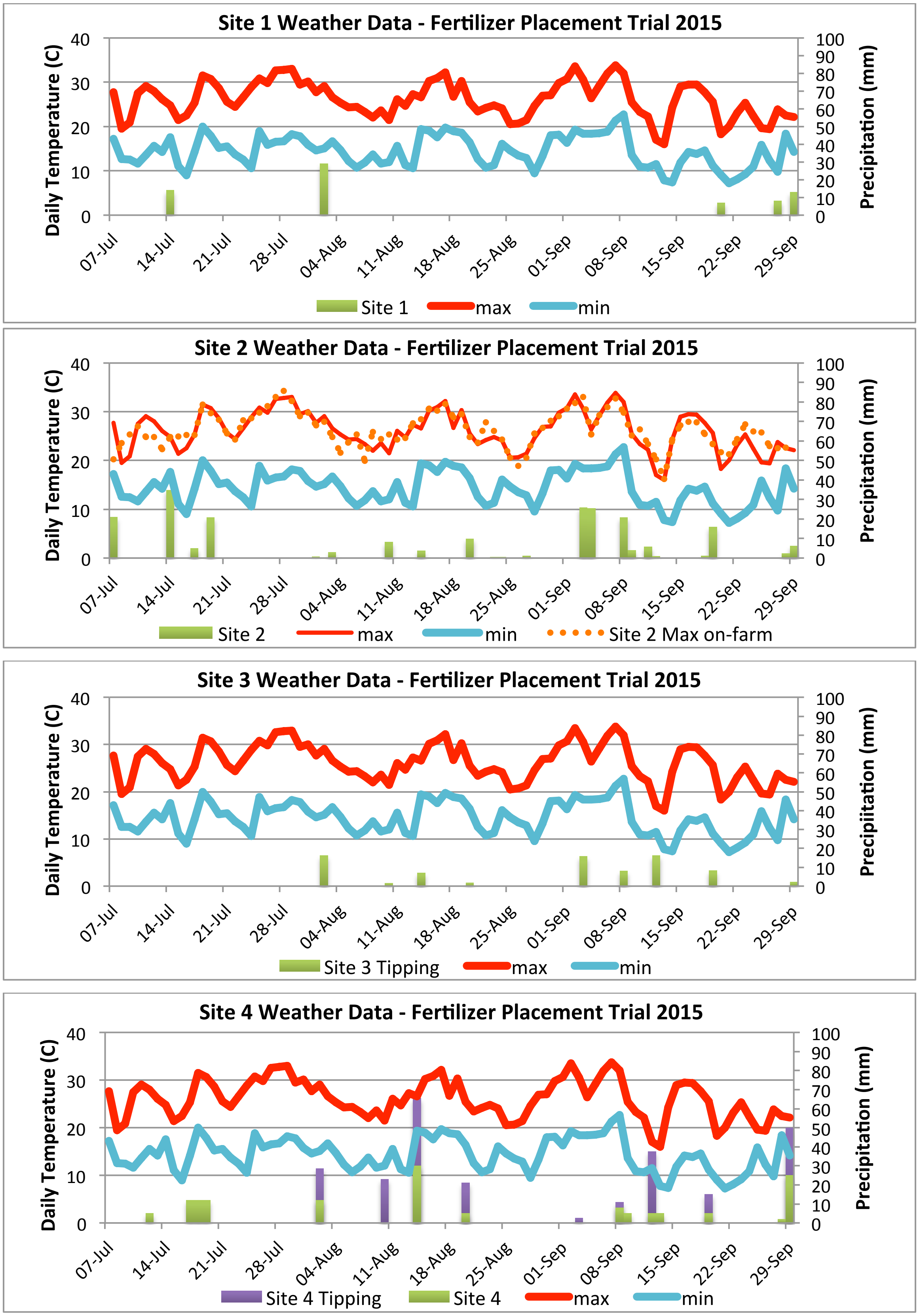

Figure 7. Weather for the four sites, using data from on-farm weather stations and Weather Underground climate data.

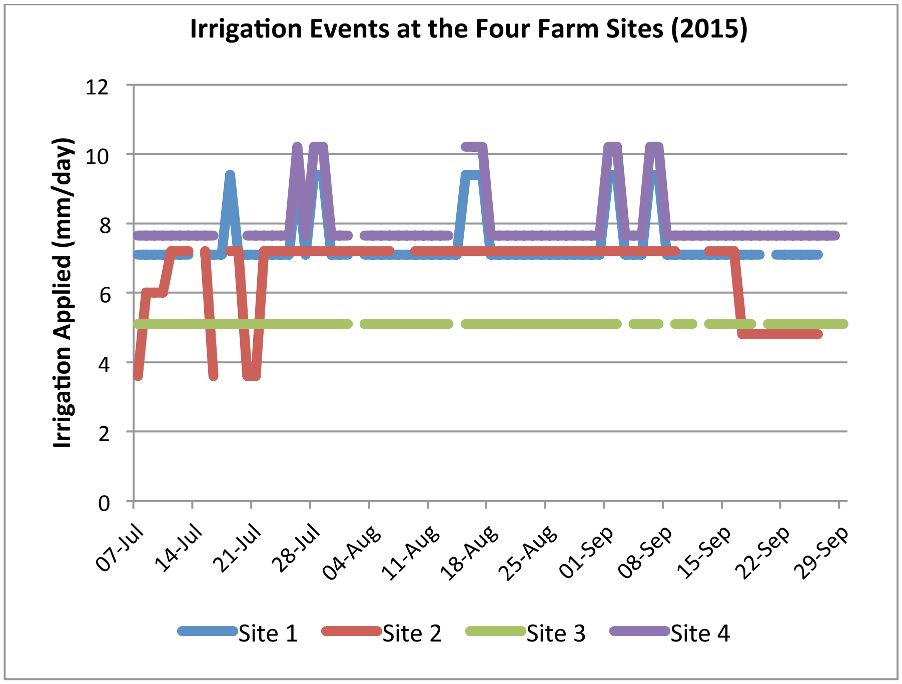

Figure 8. Irrigation events at each of the four farms. Gaps in the data are days where there were no irrigation events due to sufficient rainfall.

Table 2. Irrigation and Precipitation Amounts at the Four Sites Through the Trial Period

	Total Irrigation (mm)	Total Precipitation (mm)	Total Water Received (mm)
Site 1	593	198	791
Site 2	498	71	569
Site 3	434	119	553
Site 4	635	227	862

Table 3. Average total and minimum/maximum water applied per day in mm equivalent at Site 4 across the trial area.

	mm equiv/d		
	avg	min	max
27-Jul	5.9	3.6	7.8
30-Jul	7.9	4.3	14.1
06-Aug	4.6	3.3	6.0
24-Aug	5.2	3.0	8.2
03-Sep	4.9	1.0	8.3
01-Oct	4.4	0.8	8.8

Potential Savings

Estimated fertilizer savings based on using 20% less fertilizer for Dibble 2 method compared to the Incorporated placement method are detailed in Table 4. Both #3 and #25 container nursery pots are compared below for the main placement methods. Note that the recommended medium rate from the label for the #25 pot is extrapolated based on surface area. It is interesting to note that Site 3, whose standard fertilizer method is dibbling, uses less fertilizer than the recommended label rates, so these values were also included in Table 4. Other nurseries have also confirmed using less than manufacturer's recommendations for fertilizer for the Incorporated method (personal communication).

Table 4: Comparison of fertilizer (Polyon 16-6-12, 5-6 mo) cost per pot over 2 different pot sizes and the various main fertilizer placement methods, based on $70/20kg bag.

Fertilizer Placement/Rate	#3 pot, Cost/1000 pots	#25 pot, Cost/ 1000 pots
Dibble Site 3 normal rate	$ 94.50	$ 507.50
Dibble trial rate	$ 140.00	Not trialed
Incorporated rate	$ 175.00	N/A for large containers
Topdress rate	$ 161.00-192.50 (label medium-trial)	$ 913.50 (label medium rate)

Conclusions/Recommendations

The Incorporated fertilizer placement method most often resulted in the highest levels of nutrients in the leachate at every site. Incorporating fertilizer prills results in even distribution throughout the container media. It is thought that the nutrients in the bottom third of the container pot are leaching out of the container during irrigation and precipitation events, before they can be absorbed by the roots.

Subsurface application of fertilizer in a Dibble 2 placement resulted in reduced levels of total phosphorus and nitrate-nitrogen compared to traditional Topdress and Incorporated fertilizer placement by up to 50%. Dibble 2 fertilizer placement also resulted in 20-27% reduction in the amount of fertilizer used compared to Incorporated and Topdress placement methods. Our results indicate that the reduced rate of fertilizer in by dibbling did not have negative impact on crop growth (colour and foliar nutrient concentration). Given the high cost of fertilizers and interest in preventing nutrient loss through the leachate, subsurface application of fertilizers can significantly reduce input costs for container nursery crops. These findings are very significant, and suggest that there are Best Management Practices that can be implemented (assuming it is cost effective to apply and appropriate for the crop needs) that can improve the ability to manage nutrients on farm. However, further research should be undertaken to support the farms considering changing their fertilizer placement practices to ensure successful transition and continued production of high quality plants.

Although the subsurface method applying of fertilizers was found to reduce fertilizer nutrients in the container leachate, there are some challenges in the industry-wide adoption of this method. This method is more labour-intensive and will reduce potting efficiency. The most logical and cost-effective timing for subsurface application of controlled release fertilizer is during potting. However, applying fertilizer at the time of potting can result in fertilizer nutrient release in the container media in advance of active root growth for crops that are initially light feeders, resulting in greater loss of nutrients in the leachate and runoff during the first few weeks following potting. Also, subsurface dibbling can significantly impact root structure and may be unsuitable for some tree species.

Despite the challenges, based on the results of this study and communication with participating growers, a subsurface application of controlled-release fertilizer would be desirable in many production scenarios. The development of an automated, subsurface placement method for spreading the fertilizer into a layer (and not lateral clumps) at the time of potting or after potting would be adopted if it could be carried out efficiently to coincide with crop growth needs.

Other key finding were the substantial decrease in nitrogen, phosphorus and potassium leached for the Dibble 2, Dibble Layer and TD Cohesion treatments compared to the Incorporated benchmark. The results of this study are encouraging and will likely influence fertilizer placement decisions in commercial production systems.

Acknowledgements

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